Flight Vehicle Structural Design Processes for a Common Bulkhead and a Multipurpose Crew Vehicle Spacecraft Adapter

Pravin K. Aggarwal and Patrick V. Hull
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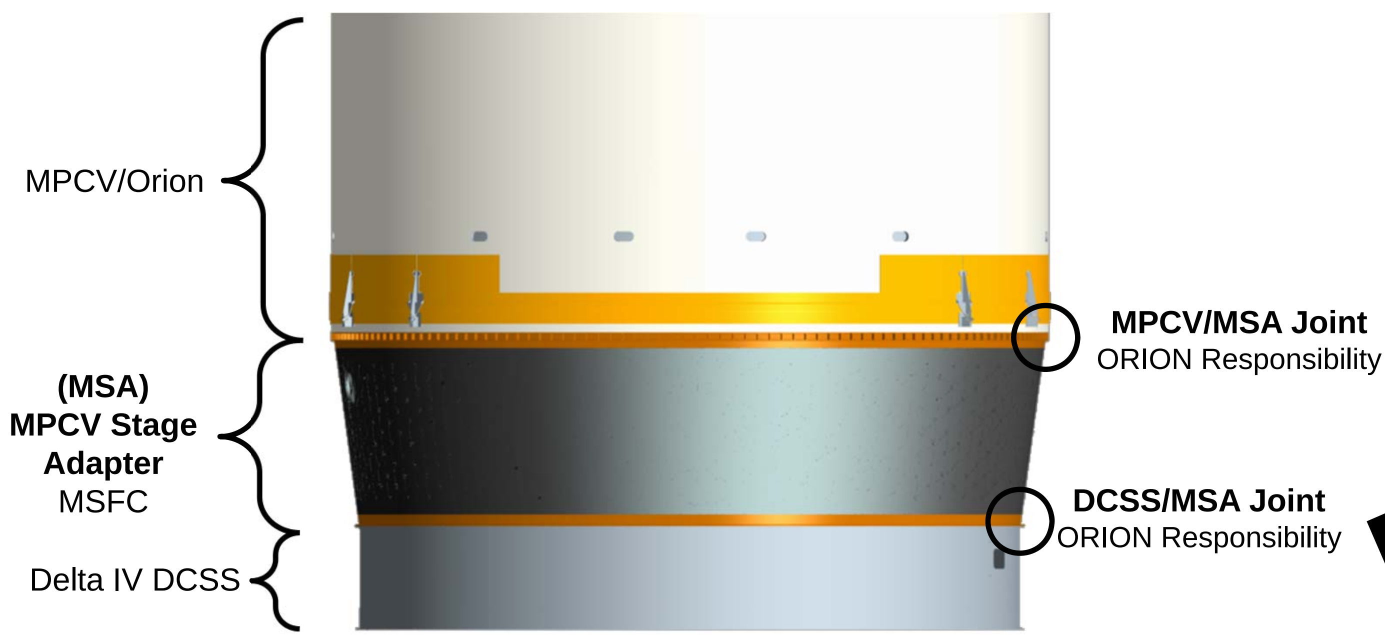
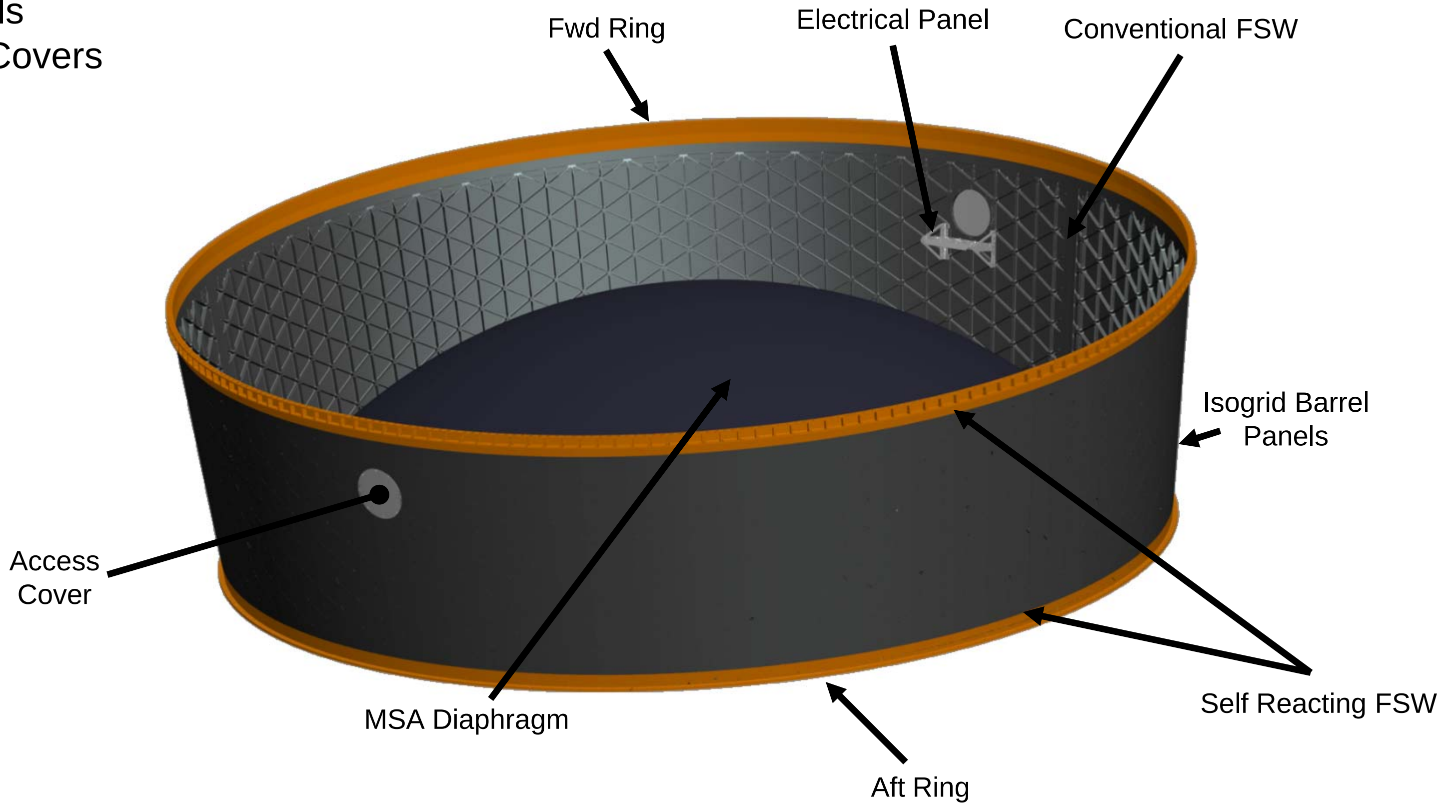
MSA: Design Overview



MSA: Design Overview

- Primary Structure
  - Single Piece Fwd & Aft Rings
  - Conical Isogrid Panels
  - All Welded Construction

- Secondary Structure
  - Diaphragm & Doghouse
  - Electrical Panels
  - Access Panel Covers



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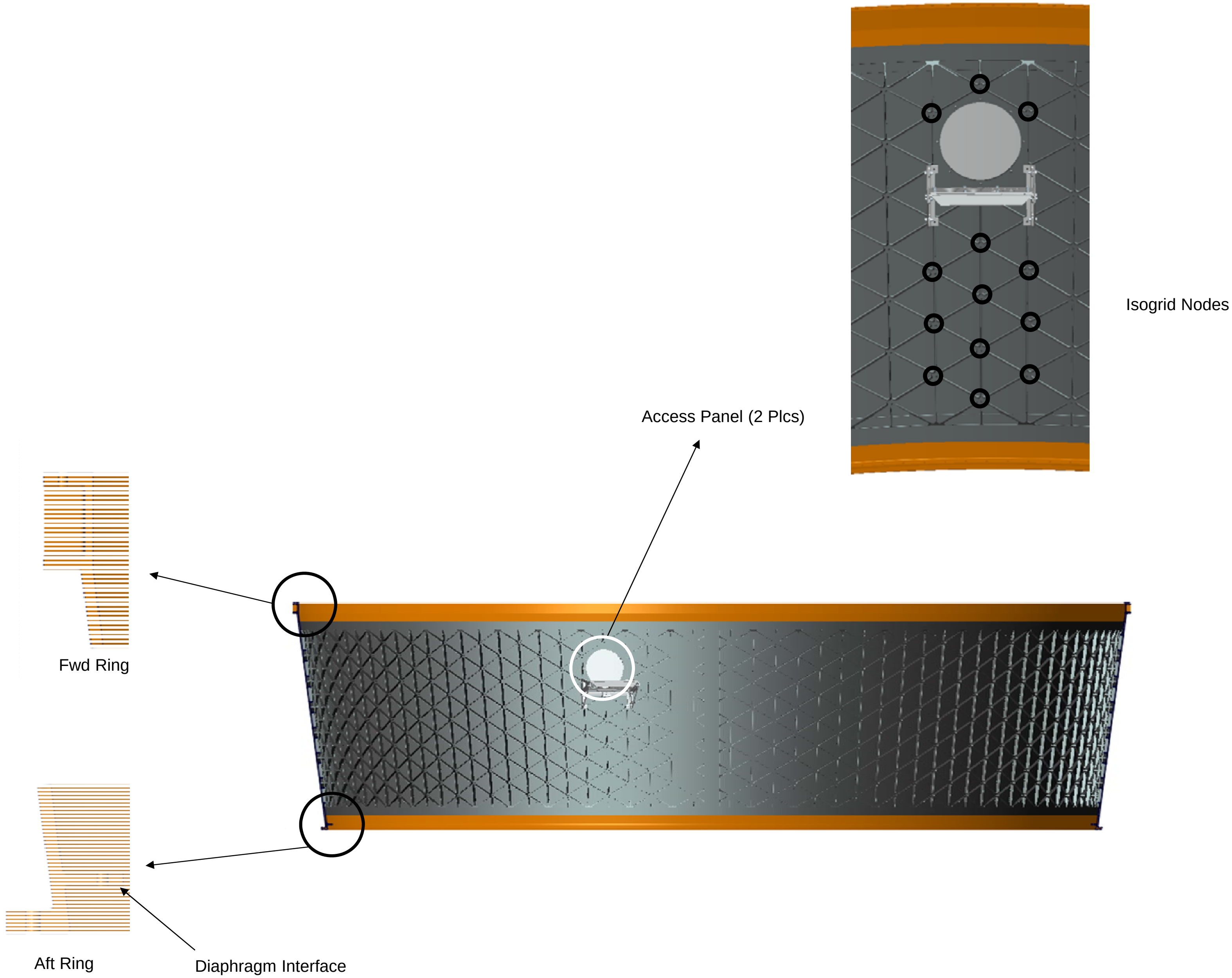
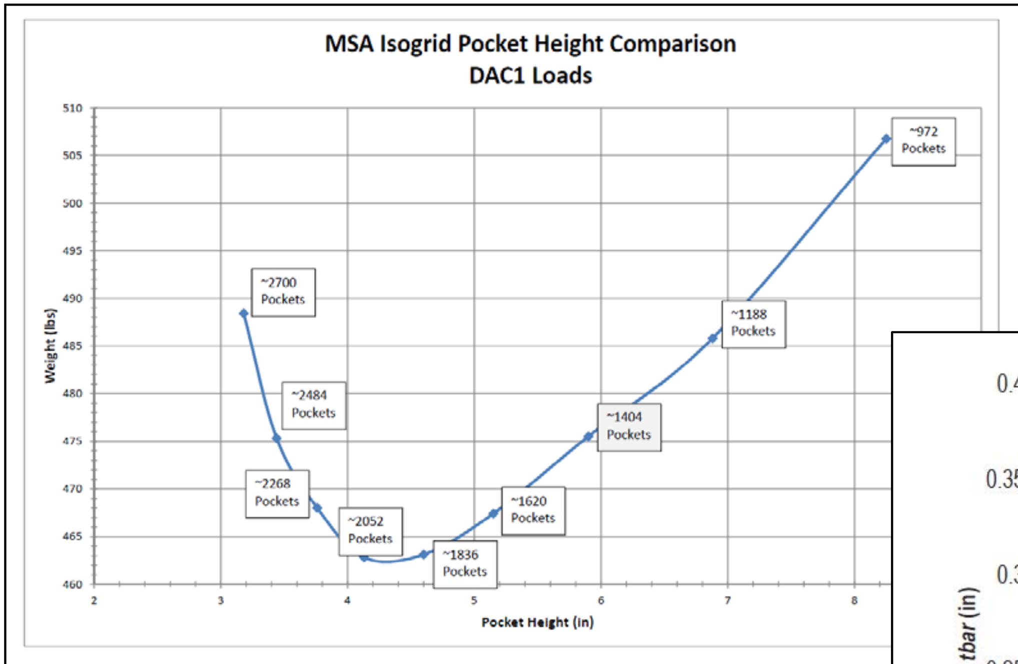
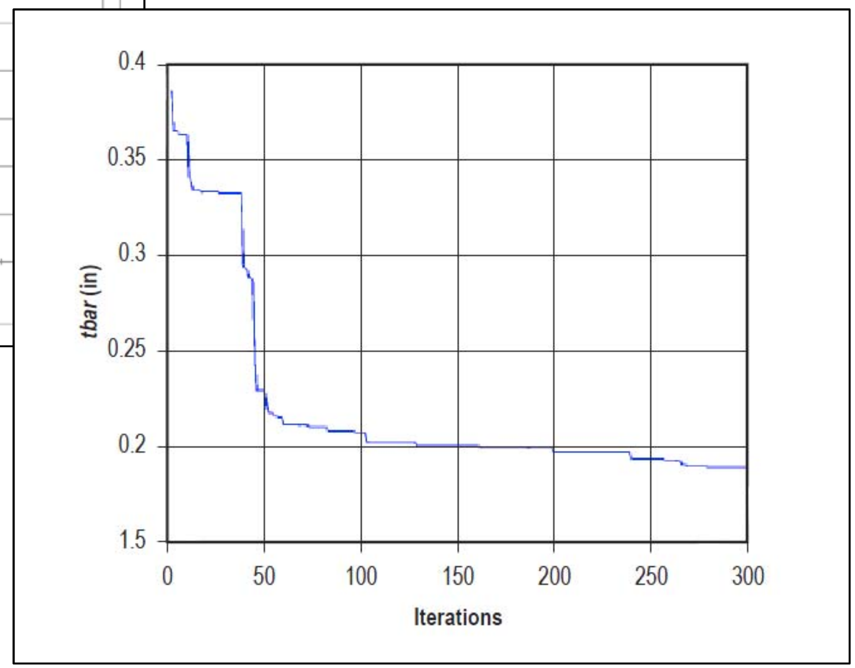
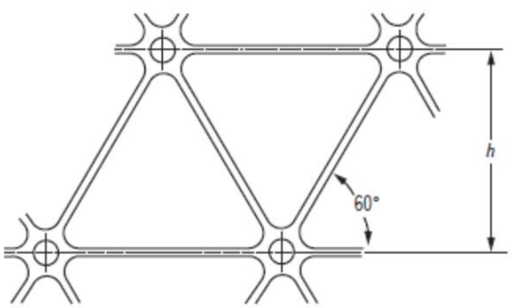
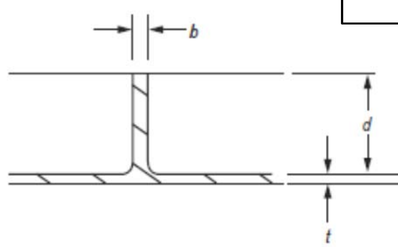


MSA: Pocket Parameter Optimization

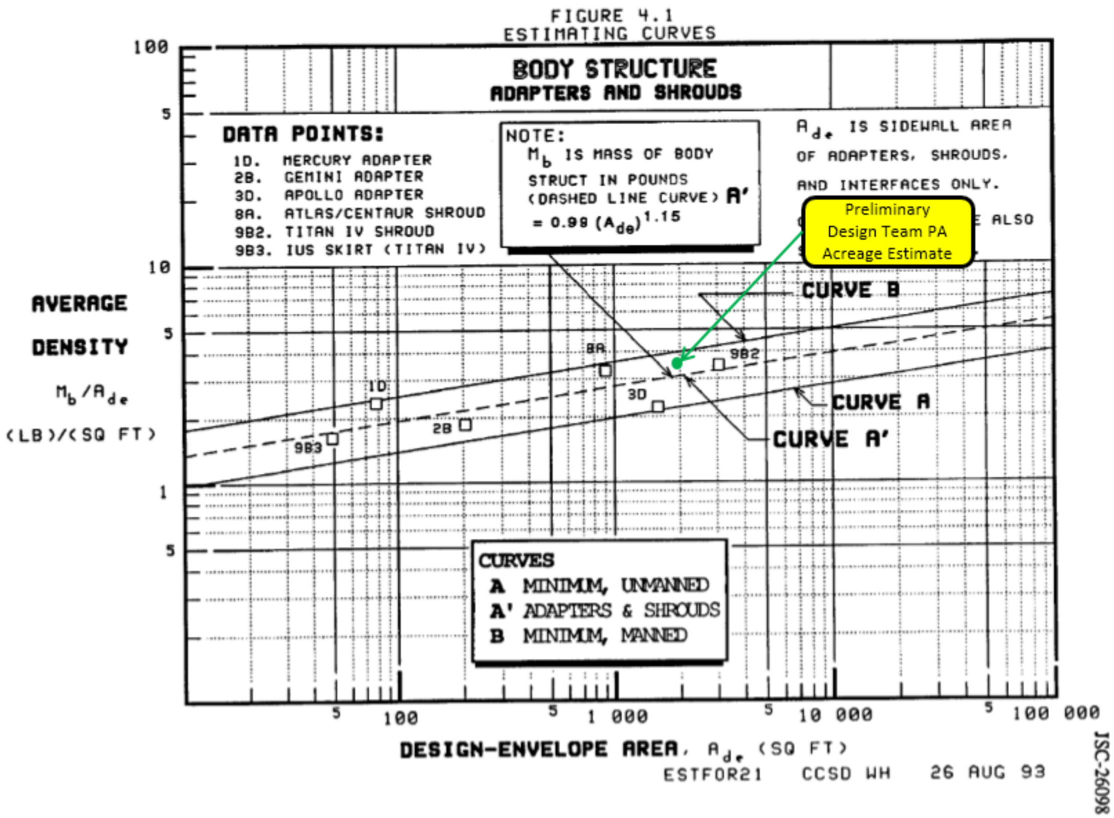








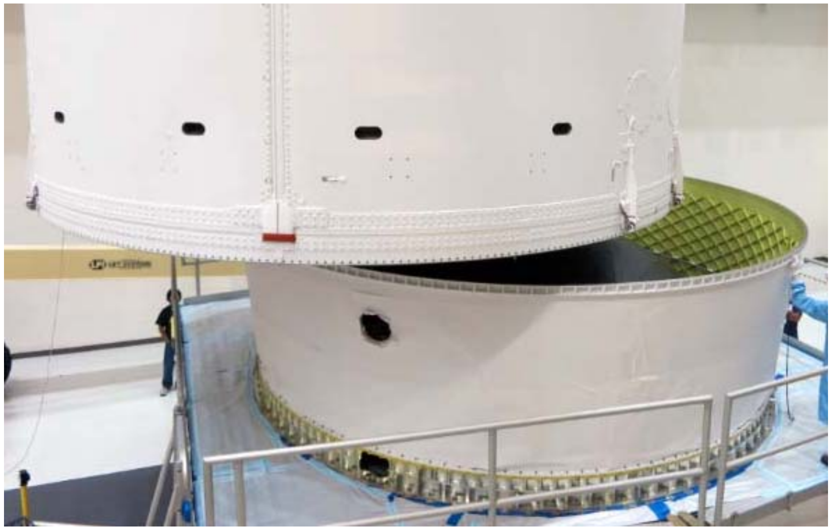
MSA: Historical Comparison



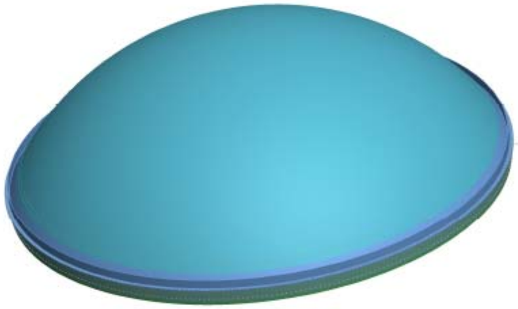
Note: Apollo Spacecraft Lunar Adapter is Metal Composite

Ref: Heineman Jr., W.: “Design Mass Properties II: Mass Estimating and Forecasting for Aerospace Vehicles Based on Historical Data,” Report No. JSC-26098, NASA Johnson Space Center, Houston, TX, November 1994.

MSA: Design Overview



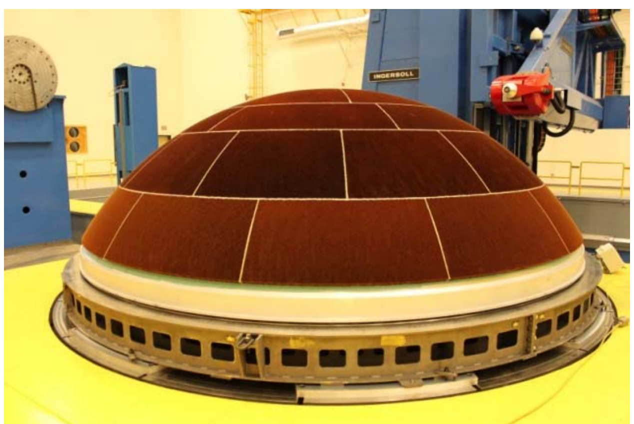
Common Bulkhead: Design Overview



Ares I Upper Stage
Common Bulkhead

Ares I Upper Stage 5.5m diameter
Pressurized Structure

Ares I



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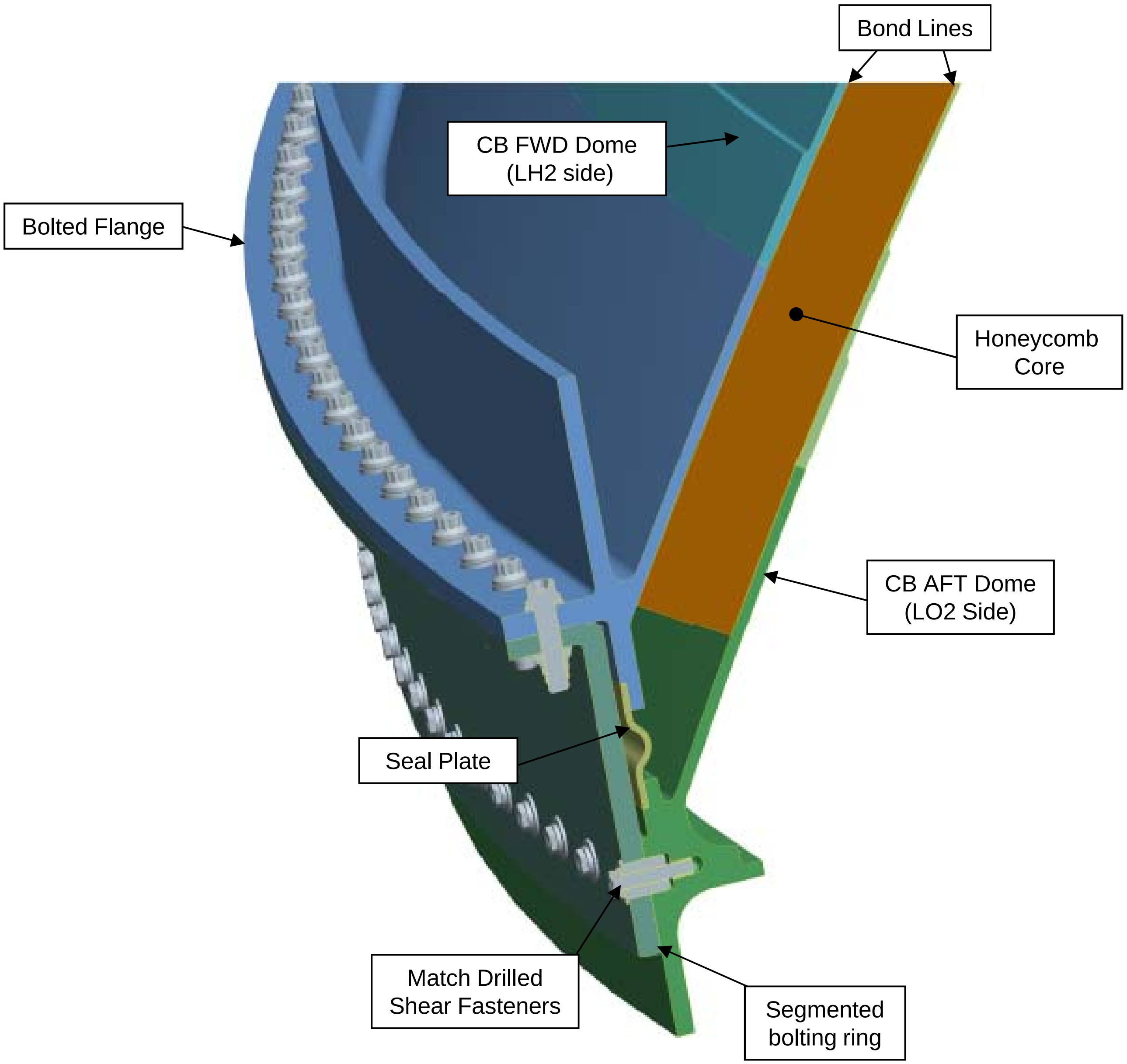
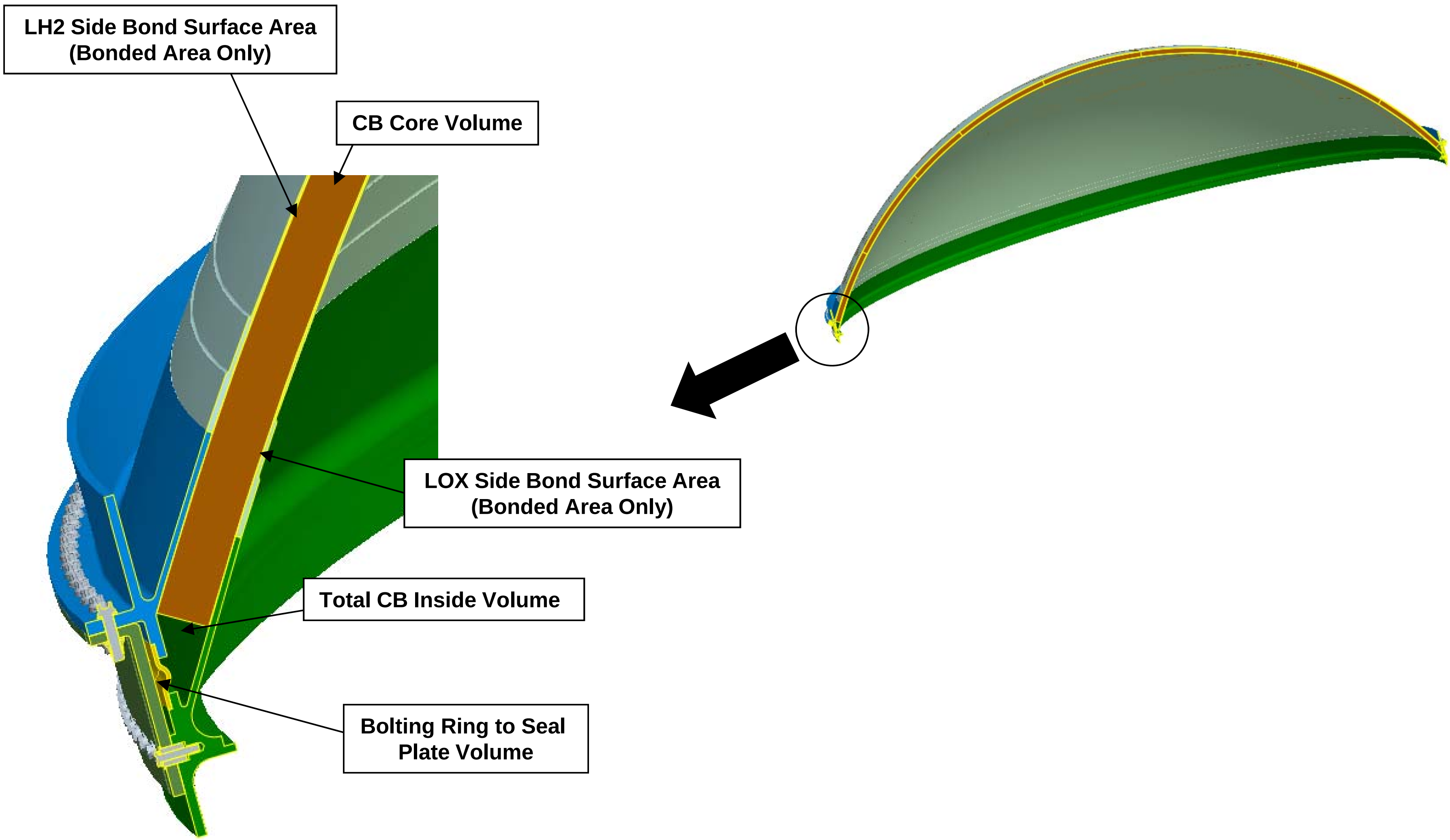
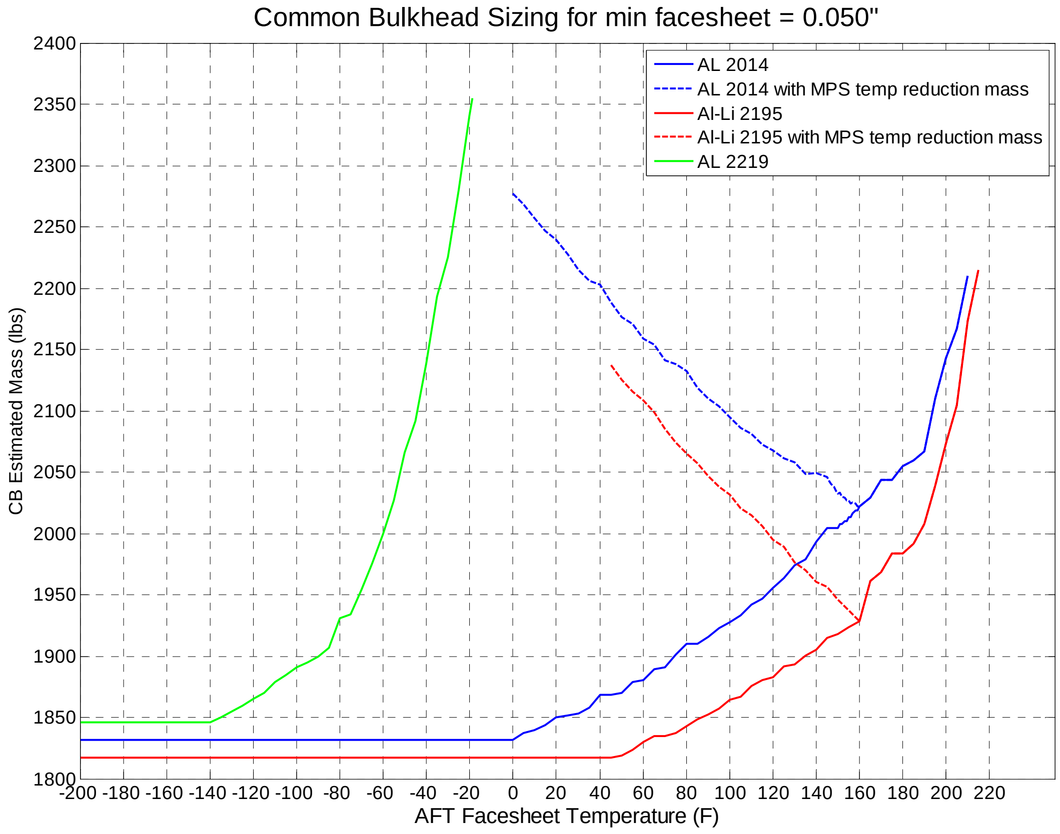


Common Bulkhead Design Overview



Common Bulkhead: Thermal Gradient

- **Thermal stress across a common bulkhead is a major contributor to the driving load case [1]**
  - Problem: Thermal mismatch along with pressure differential define the driving loads for a common bulkhead. There is a significant temperature gradient across the common bulkhead. The CB FWD dome temperature = -423F, CB aft dome temperature = high temperature ullage pressurant
  - Solution:
    - Core must have low thermal conductivity and sufficient shear strength
    - Choose dome and core thicknesses to balance thermal effect and structural efficiency
    - Hold tight tolerance on domes skin thickness for thermal stress effects
    - Reduce LO2 ullage pressurant temperature through additional chilled helium ullage pressurant

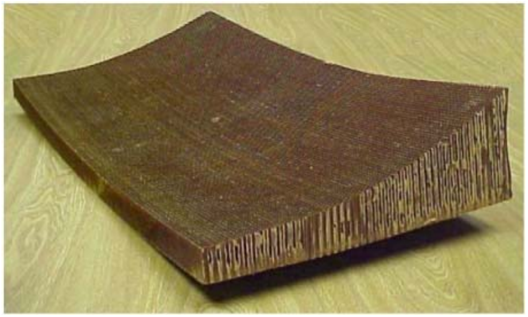


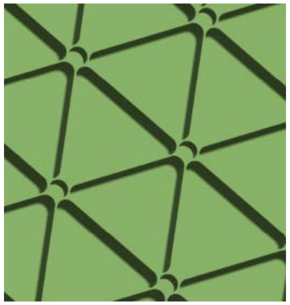
1: “Structural Design Considerations for the Storage of Liquid Hydrogen in a Space Vehicle” Sagata, note error in thermal stress equation

Common Bulkhead: Trades

Trade Study Example

- Sandwich vs. Machined / stiffened dome





	Composite Common Bulkhead	Machined / Stiffened Common Bulkhead
Mass	*Lighter*	*Heavier*
System Impact	Core volume thermal conditioning	Easier to mount auxiliary hardware to LO2 side
Design Complexity	No exterior dome insulation required	Simplified dome design
Manufacturing and Assembly	Complex core bonding to domes Hermetic seal weld around joint Match drilling of bolting ring	Isogrid machined spun form dome and joint ring forging Complex insulation installation

- Elliptical vs. Spherical Cap

Common Bulkhead: Trades cont.

♦ Stability Trades for common bulkheads

- <u>Pressure Stabilized</u>: Must maintain positive pressure on concave side of bulkhead

- <u>Structurally Stable</u>: Designed for negative pressure
  - Designed for 1g acceleration for loss of pressure during testing
  - Designed for 4+g acceleration flight loads
    - Ares was design for a loss of pressure in aft tank, this protects for inadvertent venting during testing and flight

- <u>Fail Safe FOS</u>: 1.0 for loss of pressure failure?

Common Bulkhead: Core Volume Thermal Conditioning

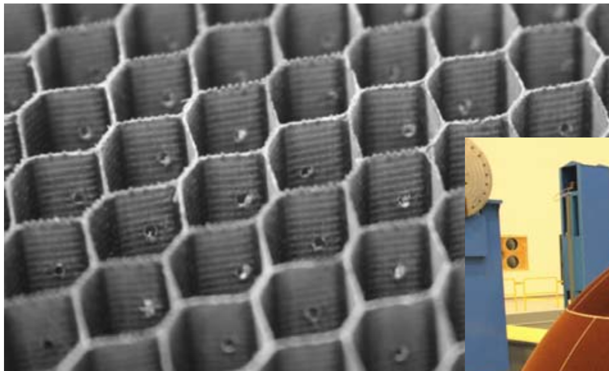
- **Design Issue: Maintaining and verifying common bulkhead volume integrity can be operationally difficult and costly**
  - Problem: Core volume environment. It is necessary to maintain a pure core volume absent of any air ingestion and provide the ability to check medium for any dome leaks.
    - To protect bondline during shelf life (moisture absorption)
    - Prohibit core pressurization during testing
    - Prevent mixing of propellants
    - Provide thermal insulation
  - Solution:
    - On pad operational access
    - Quantify leak rate of bulkhead then determine pad stay time based on total allowable pressure decay (small volume compared to tankage)
    - Monitor core from initial leak test through T0

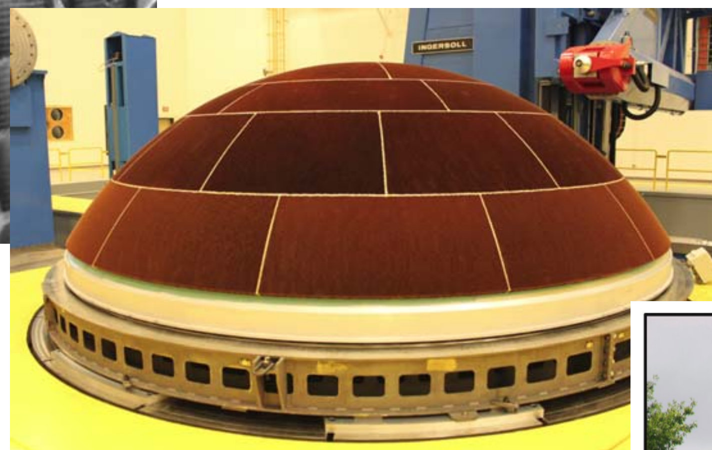
- **LCC: Excessive common bulkhead core volume pressure**
  - Core volume monitored with pressure transducers

- **If leakage does occur post T0**
  - Some ambient air with a typical atmospheric humidity ($0.026 lbm_{H2O} / lbm_{Dry\ Air}$) will be ingested into the core volume at subatmospheric pressure
  - The moist ambient air ingestion would be short lived as atmosphere depressurization occurs, immediately following this event, the moist air ingestion will be of short duration
    - Atmospheric pressure decays rapidly on ascent
  - Moisture ingestion at its maximum level is not catastrophic

Common Bulkhead: Tanking

- **Tanking generates temperature and pressure gradients across a common bulkhead**
  - A common bulkhead configuration can require additional operational constraints than a separate tank configuration
- **The following tanking sequence is based on a “sandwich” common bulkhead *conceptual* design, similar to the heritage S-IVB and S-II designs**
  - Facilities tanking first
  - LOX followed by LH2
  - Common Bulkhead driven impacts
    - Minimize ΔT across common bulkhead
    - Design is structurally sensitive to cryo-loading anomalies
    - Potential launch turnaround delays
  - Operational procedures for on-pad “core” purging
    - A different, more complex purge method may be applied for a Common Bulkhead to eliminate cryopumping or accumulation of haz gas levels.
    - Purge effluent may be analyzed for haz gas prior to launch

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